MASSACHUSETTS COASTAL AND TIDAL AREAS

LETTER

FROM

THE SECRETARY OF THE ARMY

TRANSMITTING

A LETTER FROM THE CHIEF OF ENGINEERS, DEPARTMENT OF THE ARMY, DATED JUNE 2, 1965, SUBMITTING A REPORT, TOGETHER WITH ACCOMPANYING PAPERS AND ILLUSTRATIONS, ON AN INTERIM HURRICANE SURVEY OF THE MASSACHUSETTS COASTAL AND TIDAL AREAS, AUTHORIZED BY PUBLIC LAW 71, 84TH CONGRESS, APPROVED JUNE 15, 1955

SEPTEMBER 24, 1965.—Referred to the Committee on Public Works and ordered to be printed with six illustrations

89th Congress, 1st Session - - - - - - - - - - - House Document No. 293

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U.S. GOVERNMENT PRINTING OFFICE
WASHINGTON : 1965

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LETTER OF TRANSMITTAL

DEPARTMENT OF THE ARMY
WASHINGTON, D.C. 20310

September 22, 1965

Honorable John W. McCormack

Speaker of the House of Representatives

Dear Mr. Speaker:

I am transmitting herewith an unfavorable report dated 2 June 1965, from the Chief of Engineers, Department of the Army, together with accompanying papers and illustrations, on an interim hurricane survey of the Massachusetts Coastal and Tidal Areas, authorized by Public Law 71, 84th Congress approved 15 June 1955.

Copies of the proposed report of the Chief of Engineers were furnished the Commonwealth of Massachusetts and the Departments of the Interior and Commerce. The Commonwealth of Massachusetts acknowledged receipt of the report on 20 November 1964, but to date has furnished no written views with respect thereto. The views of the Departments of the Interior and Commerce are inclosed.

The Bureau of the Budget advises that there is no objection to the submission of the proposed adverse report to the Congress. A copy of the letter from the Bureau of the Budget is inclosed.

In view of the basic data contained therein, it is recommended that this report be printed.

Sincerely yours,

Stanley R. Resor

STANLEY R. RESOR
Secretary of the Army

1 Incl
Report

COMMENTS OF THE BUREAU OF THE BUDGET

EXECUTIVE OFFICE OF THE PRESIDENT
BUREAU OF THE BUDGET
WASHINGTON, D.C. 20503

3 September 1965

Honorable Stanley R. Resor
Secretary of the Army
Washington, D. C. 20310

Dear Mr. Secretary:

Mr. Alfred B. Fitt's letter of September 1, 1965, submitted the report of the Chief of Engineers on an interim hurricane survey of the Massachusetts Coastal and Tidal Areas, authorized by Public Law 71, 84th Congress approved June 15, 1955.

The Chief of Engineers recommends that further improvements for hurricane protection in the Massachusetts coastal and tidal areas not be undertaken by the United States at this time.

I am authorized by the Director of the Bureau of the Budget to advise you that there would be no objection to the submission of the proposed adverse report to the Congress.

Sincerely yours,

E. Fenton Shepard

E. Fenton Shepard
Acting Chief, Resources
and Civil Works Division

COMMENTS OF THE DEPARTMENT OF THE INTERIOR

UNITED STATES
DEPARTMENT OF THE INTERIOR
OFFICE OF THE SECRETARY
WASHINGTON, D.C. 20240

January 6, 1965

Dear General Wilson:

This is in reply to your letter of November 17, 1964, requesting our comments on an interim hurricane survey of the Massachusetts Coastal and Tidal Areas.

This Department has no objection to your unfavorable report.

Sincerely yours,

Robert W. Wilson
Deputy Assistant Secretary of the Interior

Lt. General Walter K. Wilson, Jr.
Chief of Engineers
Department of the Army
Washington, D. C. 20315

COMMENTS OF THE DEPARTMENT OF COMMERCE

THE UNDER SECRETARY OF COMMERCE
FOR TRANSPORTATION
WASHINGTON, D.C. 20230

May 26, 1965

Lieutenant General W. K. Wilson, Jr.
Chief of Engineers
Department of the Army
Washington, D. C. 20315

Dear General Wilson:

You transmitted to us for our information and comment your report on a survey of the Massachusetts coastal and tidal areas to determine the feasibility of providing improvements for preventing loss resulting from flooding and wave action caused by hurricanes. Your report includes the reports of the Division Engineer and the Board of Engineers for Rivers and Harbors.

You note that two hurricane protection projects for the area are presently under construction. When these projects, for New Bedford-Fairhaven and Wareham-Marion, are in operation, they will together effect a reduction of about 75 percent of the losses to be anticipated in a recurrence of the record 1938 level of tidal flooding. Owing to the scattered nature of the remaining damages, you conclude that no Federal improvements for hurricane protection are warranted at this time, except for improvements that may be found feasible by future studies in the Saugus River estuary area, which involve tidal flood protection from northeast coastal storms as well as hurricanes. In the absence of structural measures in the remaining areas, you suggest a number of measures to be accomplished by local interests for preventing loss of life and flood damage to shore properties in future hurricanes.

In reviewing this report, the Weather Bureau suggests the following correction: The track for the "Great New England Hurricane, September 1938," as shown in the figure on the last page of * Appendix B, is apparently an old version of the path of this storm. A copy of this figure with the revised track entered in red is enclosed. The source for this revision is the National Hurricane Research Project Report No. 39, "Surface Winds Near the Center of Hurricanes (and Other Cyclones)." The remainder of the meteorological material appears to be correct.

* A revised page has been inserted in the report.

The Area Redevelopment Administration notes that along the coast of Massachusetts parts of Essex, Plymouth, Barnstable, and Bristol Counties and all of Dukes County are ARA designated redevelopment areas. ARA has no information on redevelopment impacts of protective works along the coast of Massachusetts that would lead it to disagree with your views. The agency concurs with the recommendations that the hurricane survey of the area be published in order to stimulate interest in the local damage-preventing actions suggested by the Division Engineer.

The Coast and Geodetic Survey note that conventional and small-craft nautical charts and geodetic control adequately cover the coastal areas involved in the report; and these may be of use to public and private interests in preparing long-range plans for full development of the lands, waters, and other natural resources of the area.

The Department of Commerce has no objections to your findings and recommendations, and appreciates the opportunity to comment on your report.

Sincerely,

Clarence D. Martin, Jr.

Enclosure

MASSACHUSETTS COASTAL AND TIDAL AREAS

REPORT OF THE CHIEF OF ENGINEERS, DEPARTMENT OF THE ARMY

HEADQUARTERS
DEPARTMENT OF THE ARMY
OFFICE OF THE CHIEF OF ENGINEERS
WASHINGTON, D.C. 20315

IN REPLY REFER TO

ENGCW-PD

2 June 1965

SUBJECT: Massachusetts Coastal and Tidal Areas

TO: THE SECRETARY OF THE ARMY

1. I submit for transmission to Congress my report on a survey of the Massachusetts coastal and tidal areas in partial response to Public Law 71, Eighty-fourth Congress, first session, with a view to providing improvements for preventing loss of human lives and damages to property resulting from flooding and wave action caused by hurricanes. My report includes the reports of the Division Engineer and the Board of Engineers for Rivers and Harbors. The reports are concerned with those portions of the Commonwealth subject to tidal flooding that have not been covered in hurricane survey reports previously submitted or currently under study.

2. The Division Engineer finds that the two authorized hurricane projects for New Bedford-Fairhaven and Wareham-Marion, when in operation, would together effect a reduction of about 75 percent of the losses to be anticipated in a recurrence of the record 1938 level of tidal flooding. Owing to the scattered nature of the remaining damages, he concludes that no improvements for hurricane protection are warranted at this time, except for improvements that may be found feasible by future studies in the Saugus River estuary area, which involve tidal flood protection from northeast coastal storms as well as hurricanes. He suggests a number of measures to be accomplished by local interests for preventing loss of life and flood damage to shore properties in future hurricanes, and recommends that no improvements for hurricane protection be undertaken by the United States at this time in the Massachusetts coastal and tidal areas, except for the authorized projects at New Bedford-Fairhaven and at Wareham-Marion, and improvements that may be found feasible by proposed studies in the Saugus River-Revere coastal area, which involve tidal flood protection from northeast coastal storms as well as hurricanes.

3. The Board of Engineers for Rivers and Harbors concludes that, in the absence of structural measures in the remaining areas, local interests should adopt and implement the measures suggested by the Division Engineer for prevention of loss of life and minimization of property damages; and noting the findings of the Division Engineer, recommends that further improvements for hurricane protection in the Massachusetts coastal and tidal areas not be undertaken by the United States at this time. The Board further recommends that these reports, with selected illustrations, be printed.

4. I concur in the views and recommendations of the Board.

W. K. WILSON, JR.
Lieutenant General, USA
Chief of Engineers

ENGBR(5 Aug 64) 1st Ind
SUBJECT: Hurricane Survey Report - Massachusetts Coastal and Tidal Areas

Board of Engineers for Rivers and Harbors, Washington, D. C. 20315
13 October 1964

TO: Chief of Engineers, Department of the Army

1. The Massachusetts coastal area consists of a part of the shores of Mount Hope Bay, an easterly arm of Narragansett Bay in Massachusetts, the mainland shores extending from the Rhode Island boundary at Westport to the New Hampshire boundary at Salisbury, and the shores of Martha's Vineyard and other Massachusetts islands. It has a tidal shoreline length of more than 1,500 miles. The coastal area contains 15 cities and 53 towns and covers a total of about 2,300 square miles. It has an estimated population of 1,926,000, and a population density of about 840 per square mile. Over 37 percent of the total Massachusetts population live in the coastal area. The population of the coastal towns increases markedly during the summer as a result of an influx of summer residents and vacationists with several of the towns experiencing increases of almost 300 percent.

2. The Federal Government has adopted projects in the area to facilitate navigation in order to meet the needs of deeper-draft vessels and the growth of recreational boating. Also, the Corps of Engineers has made studies leading to many authorized and constructed beach erosion projects. Construction of shore protective works has been undertaken by several State agencies and to a lesser extent by the coastal communities. The State has constructed a project to protect an extensive residential area in the Kenberma section of the Town of Hull.

3. Pursuant to the authorizing legislation, two hurricane survey reports have been submitted to date resulting in authorized projects for New Bedford-Fairhaven and for Wareham-Marion. A survey report on Narragansett Bay, which will include Mount Hope Bay, is under preparation. Also, studies relating to all causes of flooding in the coastal areas of the Towns of Revere, Saugus, Malden, and Lynn recently have been authorized and a report thereon will be submitted later.

4. Three great hurricanes and other great storms in the last 26 years have caused considerable loss of life and damage to public and private properties along the Massachusetts shoreline, particularly in the Buzzards Bay area, and created flood and erosion problems of

serious consequence. A recurrence of a hurricane of the magnitude of the 1938 storm would cause losses from tidal flooding of about $65 million in Massachusetts. The greatest concentration of damages would occur in the New Bedford-Fairhaven and Wareham-Marion areas where a recurrence of record tide levels would cause flood losses of about $37 million and $15 million, respectively. Along the remaining shores of Buzzards Bay and the Nantucket Sound exposure of Cape Cod the recurring hurricane tidal flood losses would be about $13 million. Operation of the New Bedford-Fairhaven project, now under construction, and the authorized project for Wareham-Marion would together prevent flood damages of about $50 million, or about 75 percent of the tidal flood damages that would occur over the entire Massachusetts coast in a recurrence of a storm of the magnitude of the 1938 hurricane. Northeast storms, occurring with greater frequency than hurricanes and with longer duration of tidal flooding and destructive wave action, have resulted in serious damages to private and public property north of the Cape Cod areas. Damages from recent storms have been estimated at $5.3 million for the storm of December 1959 and $10 million for that of January 1961. The principal damage centers north of Cape Cod include Hull, Quincy, and the Boston complex, particularly the Revere-Saugus River area.

5. The Division Engineer concludes that it would be desirable for local interests to give serious consideration to the following measures to lessen future damages from tidal flood losses:

a. Hurricane warning and emergency flood mobilization measures, including plans for evacuation and escape routes;

b. Flood-plain zoning for control of residential, industrial, and commercial building in low waterfront areas subject to hurricane tidal flooding; and

c. Flood-proofing of existing structures by measures to prevent water damage or by elevating buildings above flood level.

6. The Division Engineer recommends that no improvements for hurricane protection be undertaken by the United States at this time in the Massachusetts coastal and tidal areas except for the authorized projects at New Bedford-Fairhaven and at Wareham-Marion, and improvements that may be found feasible by proposed studies in the Saugus River-Revere coastal area, which involve tidal flood protection from northeast coastal storms as well as hurricanes.

7. The Division Engineer issued a public notice stating his recommendations and affording interested parties an opportunity to present additional information to the Board. No communications have been received.

Views and Recommendations of the Board of Engineers for Rivers and Harbors.

8. Views.--The Board of Engineers for Rivers and Harbors concurs in general in the views and recommendations of the Division Engineer. It notes that study of the hurricane-tidal flood problem in the Massachusetts part of Mount Hope Bay is included in the survey report on Narragansett Bay, presently under preparation. The Board further notes that a study of the problem of flooding by the Saugus and Pine Rivers, and by storm tides in the adjacent coastal areas, is authorized by a resolution of the Committee on Public Works of the House of Representatives, United States, adopted 23 June 1964. The Board concludes that, in the absence of structural measures in the remaining areas, local interests should adopt and implement the measures suggested by the Division Engineer for prevention of loss of life and minimization of property damages.

9. Recommendations.--Accordingly, the Board recommends that further improvements for hurricane protection in the Massachusetts coastal and tidal areas not be undertaken by the United States at this time. Because of their general interest to the public and their value to local authorities, the Board further recommends that these reports, with selected illustrations, be printed.

FOR THE BOARD:

R. G. MacDONNELL
Major General, USA
Chairman

SYLLABUS

Hurricane-driven waters have caused great loss of life and destruction of public and private property along the coast of Massachusetts. Serious problems of tidal flooding and beach erosion have resulted from hurricanes and other severe storms, including three severe hurricanes in the past twenty-six years. The most severe, in September 1938, caused tidal flooding of over 14 feet above mean sea level and a loss of 187 lives. Flooding associated with the 1944 hurricane, however, caused the highest flood levels in the outer islands and along the south shore of Cape Cod, ranging as high as 11 feet above mean sea level. The August 1954 Hurricane Carol caused flood levels of one to two feet below the 1938 flood levels along most of the southern Massachusetts coast but in the outer islands, and along the south shore of the Cape, the flood levels were about 2 feet higher than the 1938 storm. A recurrence of a hurricane of the magnitude of the 1938 storm would cause tidal flood damages totaling about $65 million.

The location of Massachusetts exposes the land to two different types of storms. The problems south of Cape Cod are quite different from those north of the Cape.

a. South of Cape Cod. The south shore of Cape Cod, the outer islands and the Buzzards Bay area to the Rhode Island State line,

are exposed to southerly winds and hurricane-generated surges which move up the Atlantic Coast. The history of hurricanes moving into New England shows that this area frequently has received the brunt of the forces from rapidly moving hurricanes. Particularly hard hit in the past was the Buzzards Bay area, from the Rhode Island State line to Falmouth, Massachusetts, where about 90 percent of the tidal flood damages were concentrated. The greatest concentration of damages was in the New Bedford-Fairhaven area where a recurrence of the 1938 hurricane would cause damages of about $37 million and in the Wareham-Marion area where damages would be about $15 million. Other damages totaling about $13 million would occur mainly at scattered locations along the remaining shore of Buzzards Bay and the Nantucket Sound exposure of Cape Cod.

b. North of Cape Cod. The north shore of Massachusetts and the north side of the Cape are vulnerable to storms with winds from the north and east. The problem is predominantly from the "northeaster" coastal storms, not hurricanes. Northeasters are more frequent than hurricanes and they occur at any time of the year although they are more numerous in the winter. Eighteen severe storms were recorded in the winter 1957-1958. Although some of the storms pass rapidly, others stall for several days while flooding recurs at each high tide and wave damage and erosion continue unabated; damage increases with each successive tide as the shore defenses are weakened. The record level

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in Boston Harbor was 15.4 feet above mean low water (10.5 above mean sea level) for the storm of February 24, 1723, which is about 5.9 feet above the stage of mean high water. Damages from recent storms has been estimated at $5,300,000 for the storm of December 1959, and $10,000,000 for the storm of January 1961. The principal damage centers north of Cape Cod include Hull, Quincy, and the Boston Complex, particularly the Revere-Saugus River area. The Commonwealth of Massachusetts has constructed tidal flood protection works in the Kenberma section of Hull, and a number of shore protection improvements including seawalls, revetment and beach erosion control measures which yield partial protection against coastal floods. Other improvements are being considered by the Commonwealth of Massachusetts and the Metropolitan District Commission.

The hurricane flood protection projects, under construction for New Bedford and Fairhaven, and authorized for Wareham and Marion, would prevent about $50 million or over 75 percent of the Massachusetts tidal flood losses that would be experienced in a recurrence of the great hurricane of 1938. The remaining damages are widely distributed over more than 1,500 miles of shoreline.

The Division Engineer concludes that it would be desirable for local interests to give serious consideration to the following measures to lessen future tidal flood losses:

a. Hurricane warning and emergency flood mobilization measures, including plans for evacuation and escape routes.

b. Flood-plain zoning for control of residential, industrial and commercial building in low waterfront areas subject to hurricane tidal flooding.

c. Flood-proofing of existing structures by measures to prevent water damage or by elevating buildings above flood level.

The Division Engineer recommends that no improvements for hurricane protection be undertaken by the United States at this time in the Massachusetts Coastal and Tidal Areas, except for completion of the authorized project at New Bedford-Fairhaven, and at Wareham-Marion; and improvements that may be found feasible by future studies in the Greater Boston area, including the Saugus and Pines Rivers coastal areas, which involve tidal flood protection from northeast coastal storms as well as hurricanes.

U. S. ARMY ENGINEER DIVISION, NEW ENGLAND
CORPS OF ENGINEERS
424 TRAPELO ROAD
WALTHAM, MASS. 02154

DRESS REPLY TO
DIVISION ENGINEER

REFER TO FILE NO.

NEDED-R

5 August 1964

SUBJECT: Hurricane Survey Report - Massachusetts Coastal and Tidal Areas

TO: Chief of Engineers
Department of the Army
Washington, D. C.

AUTHORITY AND INTRODUCTION

1. In view of the severe damages sustained from hurricanes along the eastern and southern coastal areas of the United States, the 84th Congress, 1st Session, adopted 15 June 1955, Public Law No. 71, which authorized the Corps of Engineers to undertake a study of means to prevent the loss of human lives and damages to property from hurricane tidal flooding.

The authorizing legislation provides that first consideration be given to areas where severe damages have occurred. Following this criteria, studies have been completed and protective projects authorized by Congress for the New Bedford-Fairhaven and the Wareham-Marion areas. Detailed information on each of the authorized projects is available in the individual survey reports. The Mt. Hope Bay area of Massachusetts, including the city of Fall River, will be included in the hurricane survey report on Narragansett Bay.

Studies for this report cover the remaining Massachusetts coastal and tidal areas for which previous hurricane survey reports have not been prepared. The results of these studies are intended to indicate the problem areas and serve as a guide for future planning.

DESCRIPTION

2. The Massachusetts coastal area extends from the Rhode Island boundary at Westport to the New Hampshire boundary at

Salisbury and has a tidal shoreline length of about 1,500 miles. It includes the shore bordering the Gulf of Maine, Massachusetts and Cape Cod Bays, Nantucket and Vineyard Sounds, Buzzards Bay and the larger open bodies of water which form or branch from the above.

The shoreline is irregular containing numerous bays and small coves and varies in topographical features from sandy dune, off-shore sand bars and sandy spits to rocky headlands with pocket beaches, or flat marshland areas.

Among the most prominent indentations along the coast is Buzzards Bay located on the southern exposure which contains New Bedford Harbor. Boston Harbor on the eastern exposure is the largest harbor in New England formed by offshore islands and the headlands of the mainland. Cape Cod, a sandy peninsula with miles of seashore and sandy beaches, attracts great numbers of vacationists during the summer season.

The coastal area contains 15 cities and 53 towns, and including Martha's Vineyard and other Massachusetts Islands, covers a total area of about 2,300 square miles.

ECONOMIC DEVELOPMENT

3. General. Manufacturing, centers of research and education, commercial navigation, recreational activities consisting largely of small boating, swimming, and a substantial tourist trade play a major role in the economy of the area.

The coastal area has a well established network of modern highways, Federal, state and local. A circumferential highway around the Boston Complex affords easy access for north-south traffic.

The area is served by three major railroads, the Boston and Maine, the New York, New Haven & Hartford Railroad and the Boston and Albany Railroad. The area is also served by a number of commercial airlines out of Logan International Airport. Numerous local and cross-country flights are available and several airlines provide transportation to points outside of the United States.

The Boston area with its complex and highly concentrated developments is in a state of extensive redevelopment at this time, including highways, shorefront, large apartment and office buildings.

4. Population. The Massachusetts coastal area has a population of 1,926,000 (1960 Census) and a population density of about 840 per square mile. Over 37 percent of the total Massachusetts population live in the coastal area. This is a decrease of about 700,000 in the ten years since 1950 and reflects mainly the movement of families from the larger cities to the suburbs. About seventy percent of the total population of the coastal area is contained in ten cities, Boston, Cambridge, New Bedford, Somerville, Lynn, Quincy, Medford, Weymouth, Everett and Revere which range in population from about 700,000 in Boston to 45,600 in Everett, 1960 Census. The population of the coastal towns increases markedly during the summer, as a result of an influx of summer residents and vacationists, with several of the towns experiencing increases of almost 300 percent.

5. Industry. The coastal area is highly industrialized, industry being concentrated in Boston and the cities to the north, such as Cambridge, Somerville, Everett, Chelsea, Lynn and Salem, and in the area to the south. Among the more important industries in the area are printing and publishing, food processing, leather goods, chemicals, machinery, tools, foundry products, apparel and paper and allied products. Also high on the list of manufactured items are textiles, automotive parts and supplies, precision instruments, rubber products and transportation equipment. Industrial development in the fields of electronics and plastics has increased rapidly in recent years.

The construction and repair of all types of ships is an important industry in the area. The Boston Naval shipyard at the mouth of the Mystic River is primarily engaged in the repair of Naval vessels while the General Dynamics Corporation has facilities for the construction of nuclear submarines at the former location of Bethlehem Steel Company at the Fore River Shipyard. A number of other smaller boatyards engaged in the building and repair of small commercial and pleasure craft are located at various points along the coast.

Commercial fishing is another major industry with Boston, Gloucester, and New Bedford handling large quantities of fish and shellfish.

6. Navigation and Commerce. Boston, the largest city in the area, has long been noted as one of the important financial centers of the country and is a focal point for banking, investments, imports, commodity brokerages and shipping in New England. The harbor and terminal facilities of Boston and environs accommodate a large volume of coastwise and foreign freight and passenger traffic each year. More than 15,000,000 tons of waterborne commerce enter the port of Boston annually.

The Cape Cod Canal is used by commercial and recreational craft as it affords convenient, safe passage between Boston and points south. Traffic through the canal amounted to about 11,000,000 tons in 1962.

The recorded history of improvements to the rivers and harbors of Massachusetts dates back to the 1820's. Over the years as the growing use of deep draft vessels increased and with an increase in recreational boating the Federal government has adopted projects to facilitate navigation. (For listing of prior studies and reports see Appendix A.)

In addition to the extensive improvements provided by the Federal government, the Commonwealth of Massachusetts has been active in improving numerous channels and anchorages, or boat basins. Also, it has constructed jetties, breakwaters, wharves and piers and other works for the protection of the coastline.

7. Recreation. The 1,500 miles of shoreline offer opportunities for outdoor activities. Recreational boating, salt water fishing and salt water bathing are popular. Yacht clubs and marinas situated in the coastal towns provide facilities for boat owners. The development of the Cape Cod National Seashore will also greatly expand opportunities for all types of outdoor activities.

TIDAL FLOODING

8. The history of hurricanes and other severe storms in Massachusetts dates back to August 1635. The distribution of recorded hurricane occurrences, mostly south of Cape Cod by estimated degree of intensity, is shown in the following table:

TABLE 1

HURRICANE OCCURRENCES, MASSACHUSETTS COAST

NUMBER OF OCCURRENCES

Period	Severe Tidal Flooding	Moderate Tidal Flooding	Flood Alert with Minor or no Tidal Flooding	Total Events
1635-1700	2	No record	No record	2
1701-1800	3	2	2	7
1801-1900	5	8	4	17
1901-1963	3	15	27	45
	13	25	33	71

The fact that there is a record of 45 hurricanes experienced in the period 1635 to 1900 indicates a lack of records during the earlier period rather than a trend toward increased hurricane activity in recent years.

The hurricane and storms that caused the most severe tidal flooding in recent times, listed in their order of magnitude for the greater part of the coast, were those that occurred in 1938, 1954, 1944 and 1960. Tidal stillwater levels associated with the three major hurricanes are given in Table 2 for several locations along the southern coast of Massachusetts. North of Cape Cod, flood levels associated with the three major hurricanes were not severe.

Past hurricanes have resulted in serious tidal flooding along the south shore including the Buzzards Bay area, particularly with winds from the south. North of the Cape the problem of tidal flooding from hurricanes has been less serious. Although winds have been high they have been parallel to or offshore minimizing onshore wave action and tidal buildup. North of the Cape winds from the northeast quadrant have caused the greatest tidal flood and wave damages.

Frequent fall, winter, or spring storms have also caused flooding problems along the south shore. As recently as November 1963 a storm with high southwest winds caused flooding of low-lying areas and wave damage along the south shore, particularly in the Buzzards Bay area.

North of Cape Cod, fall, winter and spring storms occur frequently and with winds generally from the east to northeast have caused serious tidal flooding with levels about 3 feet higher than a spring tide. These storms are of longer duration than hurricanes, can stall and last for as long as three days with prolonged damaging effects. In the winter of 1957-1958, 18 winter storms occurred causing serious tidal flood problems north of Cape Cod. Other recent severe storms occurred in December 1959, January 1961 and November 1963. Table 3 contains a list of some of the more severe storm tide levels that have been recorded at Boston.

HURRICANE PROTECTION PROJECTS

9. In response to the Congressional directive contained in Public Law No. 71, detailed investigations have been made of areas along the Massachusetts coast where heavy concentrations of tidal flood damages have been experienced. These studies have resulted in the authorization of protective works at two localities. Construction of the hurricane tidal flood protection project for the New Bedford-Fairhaven area is now in progress. The

TABLE 2

HURRICANE TIDAL STILLWATER LEVELS
MASSACHUSETTS COAST
(south of Cape Cod)

Location	Normal High Tide (ft, msl)	Hurricane Sept. 21, 1938 (ft, msl)	Hurricane Aug. 31, 1954 (ft, msl)	Hurricane Sept. 14, 1944 (ft, msl)
Westport	1.5	12.2	11.4	-
New Bedford (1)	2.0	12.6	12.0	-
Wareham (1)	2.3	14.2	13.6	-
Bourne (1)	2.3	14.2	13.6	-
Falmouth (2)	0.5	7.6	9.2	11.0
Chatham (2)	1.9	5.2	7.7	9.3
Martha's Vineyard	1.0	6.9	7.6	7.3

(1) Buzzards Bay
(2) Nantucket Sound

TABLE 3

STORM FLOOD LEVELS AT BOSTON

Date	Elevation (ft. above m. s. l.)
24 February 1723	10.5
16 April 1851	10.0
26 December 1909	10.0
27 November 1898	9.5
29 December 1959	9.4
21 April 1940	9.0
4 March 1931	8.8
30 November 1944	8.8
20 January 1961	8.8
7 March 1956	8.6
7 April 1958	8.5

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estimated cost of the project is $18,400,000. The other authorized hurricane tidal flood protection project is for the Wareham-Marion area at an estimated cost of $5,445,000. In addition, the Commonwealth of Massachusetts has constructed a project to protect an extensive residential development in the Kenberma area of Hull against tidal flooding.

HURRICANE TIDAL FLOOD DAMAGES

10. Past damages from hurricane tidal flooding have been extensive. Surveys made after the 1938 and 1954 events reveal large property losses. A recurrence of a hurricane of the magnitude of the 1938 storm would cause losses from tidal flooding of about $65,000,000 in Massachusetts. The greatest concentration of damages would occur in the New Bedford-Fairhaven and Wareham-Marion areas where a recurrence of record tide levels would cause flood losses of about $37,000,000 and $15,000,000 respectively. Along the remaining shore of the Buzzards Bay area and the Nantucket Sound exposure of Cape Cod the recurring tidal flood loss would be about $13,000,000. Damages along the Massachusetts coast north of Provincetown to the New Hampshire state line would be small. The damages that can be expected in a recurrence of the three great hurricanes of 1938, 1944 and 1954, with no protection, are given in Table 4 on the following page.

ADDITIONAL PROTECTIVE MEASURES

11. The entire shorefront of Massachusetts is subjected to a variety of forces ranging from tidal flooding to erosion and damage to existing shorefront structures by wave action.

The scattered nature of tidal flood damage throughout many miles of the shorefront and along numerous estuaries and coves limits opportunities for economical protection. The Massachusetts beaches are extensively used during the summer and the estuaries and coves along the shore attract recreational boating. As population expands and recreation pressures become even more intense, the provision of protective measures to retain these valuable resources will be found desirable.

Protective measures that may be taken to prevent future loss of life and reduce tidal flood damages fall into the following general classes:

a. Positive protective structures. Positive protective measures include structures such as breakwaters, seawalls, dikes, revetments, dune restoration and beach raising and widening. Shore protection measures such

TABLE 4

HURRICANE TIDAL FLOOD DAMAGES
MASSACHUSETTS COASTAL AND TIDAL AREAS
(Thousands of Dollars - 1964 price level)

Location	Recurring 1938 Hurricane	Recurring 1944 Hurricane	Recurring 1954 Hurricane
Buzzards Bay Area			
Westport-Dartmouth	2,200	400	1,800
New Bedford-Fairhaven	37,000	1,800	32,000
Mattapoisett	3,300	200	2,600
Wareham-Marion	15,000	1,100	11,100
Cape Cod Area			
Bourne-Falmouth (Buzzards Bay Shore)	4,900	200	3,600
South Shore	1,600	5,800	3,300
North Shore	200	minor	100
Offshore Island			
Martha's Vineyard-Nantucket	500	1,500	1,200
Boston Complex & North Shore	300	minor	300
TOTALS	65,000	11,000	56,000

TABLE 5

STORM TIDAL FLOOD DAMAGES
MASSACHUSETTS COASTAL AND TIDAL AREAS
(Thousands of Dollars)

Location	Storm of December 1959	Storm of January 1961	Storm of November 1963
Buzzards Bay Area	minor	minor	1,700
Cape Cod Area			
South & West Shore	minor	minor	300
North Shore	100	200	minor
Offshore Island	minor	minor	minor
North Shore of Cape to Boston Complex	1,380	2,900	minor
Boston Complex	3,641	6,800	minor
North of Boston Complex	179	300	minor
TOTALS	5,300	10,000	2,000

as reveting, dune reinforcement and beach treatment would offer partial flood protection to inland properties. Such work can be combined with other water resource development measures as they become desirable and economical.

b. Flood-proofing, strengthening, or relocating existing buildings. Since the occurrence of Hurricane Carol and other serious storms many buildings within the flood zone have been relocated or raised on their foundations placing the first floor level above the height of expected future hurricane tides. To further mitigate future losses consideration should be given to permanent relocation of goods and equipment to higher floor levels, relocation of buildings out of the flood plain, flood-proofing and more substantial construction to resist the destructive forces of high water and waves.

c. Restrictive zoning regulations and building codes. The adoption of flood-plain zoning regulations and modified building codes can be effective steps in governing the future development of flood-prone areas to make them less vulnerable to the hazards of tidal flooding.

d. Hurricane and storm warning and emergency flood mobilization measures. Hurricane or serious storm warning mobilization measures are feasible measures to lessen future property damage and reduce danger to life. An example of mobilization measures that can be taken is contained in a report entitled, "A Model Hurricane Plan for a Coastal Community." This report was prepared in 1959 by the Weather Bureau, U. S. Department of Commerce, in collaboration with the Corps of Engineers.

SHORE EROSION

12. The erosion of beaches and damage to the shore is largely dependent upon the character of the material that composes the shore. Coarse, rocky shores are less subject to erosion than those composed of finer unconsolidated materials. Most of the Massachusetts shoreline is composed of unconsolidated materials. Between headlands of exposed bedrock, pocket beaches are formed by the erosion processes of unconsolidated materials which provide the building material for the beaches. In many areas, however, depletion of sand supply by erosion processes and construction of protective works following the intensive development of the area has cut off the necessary source of building material.

Wind-generated waves breaking along the shore set up littoral currents that are principally responsible for erosion of beaches. As described under tidal flooding, the south shore has been subjected to

hurricane-driven waves and frequent winter storms with prevailing southerly winds whereas the shore north of Cape Cod experiences more damage from easterly storms than hurricanes. These winter storms are likely to be of long duration with continuous erosion and damage of shorefront structures.

SHORE RESTORATION AND PROTECTIVE MEASURES

13. Construction of shore protective works has been undertaken by several State agencies, and to a lesser extent by the coastal municipalities. Since the adoption in 1930 of Public Law 520 establishing the Federal interest in shore protection, the Corps of Engineers has participated in the provision of protective works. Extensive studies have been made of the erosion processes leading to plans for protection. For listing of these studies see Table A-1 in Appendix A.

The natural land features existing along the coast of Massachusetts provide protection for many of the developments that lie on the coastal plain. The land features that provide protection consist of beaches either with or without natural dunes, barrier beaches fronting wide marshlands, sand bars and spits that form sheltered harbors, sand cliffs, and exposed ledge rock. The principal problem is one of continual deterioration and erosion of the beaches. Damage to the shorefront has been most serious during hurricanes and other severe storms.

The restoration of the natural features as well as the maintenance of the artificial protective measures involves a continuous inspection and maintenance program. In areas where erosion of beaches is prevalent, artificial means may be taken to replace losses and to restore them to their natural state. This may be accomplished by the following measures:

a. Stockpiling sand on the beach where it may be distributed laterally by wave action;

b. Forming artificial dunes along the backshore to provide beach nourishment through erosion of their seaward face; and

c. Direct placement of sand in conjunction with the construction of a groin system.

The land features, other than beaches, that provide natural protection are more in need of a means of stabilization rather than a restoration

to their original form. This stabilization can be accomplished by revetment, placement of rock dikes, or by the use of vegetation cover.

IMPROVEMENTS CONSIDERED

14. The principles of hurricane tidal flood protection, shore protection and related water resource development have been applied to the problem areas of the Massachusetts Coast subject to tidal flooding. General plans, and methods of protection, based upon proven coastal engineering practices, were developed for the areas of concentrated damages. These general plans with maps of the area subject to tidal flooding are contained in Appendix D to serve as a guide to future integrated public and private development. It was found that, outside of the previously studied New Bedford-Fairhaven and Wareham-Marion areas, under present economic conditions and current requirements for Federal participation, additional hurricane protection would not be warranted due to the wide distribution and scattered nature of damages except for one area where additional study is required. This is the tidal estuary of the Saugus River in the Revere Beach area which is further discussed in Appendix D.

DISCUSSIONS AND CONCLUSIONS

15. Past hurricane damages have been heaviest in the Buzzards Bay area. The southernmost shorefront of Cape Cod has nevertheless been subject to damage and severe erosion processes during hurricanes and the coast north of the Cape has been subjected to lesser damage from hurricane-driven waves. Northeast storms, occurring with greater frequency than hurricanes and with long duration tidal flooding and destructive wave action have resulted in serious damages to private and public property north of the Cape Cod areas.

Studies made for this report sought solutions to the remaining shoreline problems outside of those areas where hurricane protection would be afforded by the two authorized Federal hurricane protection projects. In the Buzzards Bay area, the New Bedford-Fairhaven project, now under construction, and the authorized hurricane tidal flood protection project for the Wareham-Marion area together would prevent tidal flood damages of about $50,000,000 from a recurring hurricane of the 1938 magnitude. This accounts for over 75 percent of the tidal flood damage that would occur along the entire Massachusetts Coast in a repetition of this storm with present day conditions.

Because of the scattered nature of the remaining damage areas additional hurricane protection appear impractical at this time, with the

possible exception of the Saugus River estuary area. Other measures can be used to augment the protection provided by these projects including flood-plain zoning, warning, flood-proofing and emergency evacuation plans to reduce future damage and prevent loss of life in the unprotected areas. From a long range viewpoint shore protection and erosion control measures can be constructed when warranted to afford a measure of protection against hurricanes and severe storms and to preserve the beaches.

It is concluded that it would be desirable for local interests to give serious consideration to the following measures to lessen future damages and prevent loss of life from tidal flooding:

a. Hurricane warning and emergency flood mobilization measures, including plans for evacuation and escape routes.

b. Flood-plain zoning for the control of residential, industrial and commercial building in low waterfront areas subject to hurricane tidal flooding.

c. Flood-proofing of existing structures by measures to prevent water damage or by elevating buildings above flood level.

RECOMMENDATIONS

16. It is recommended that no improvements for hurricane protection be undertaken by the United States at this time in the Massachusetts Coastal and Tidal Areas, except for the authorized projects at New Bedford-Fairhaven, and at Wareham-Marion, and improvements that may be found feasible by proposed studies in the Saugus River-Revere coastal area, which involve tidal flood protection from northeast coastal storms as well as hurricanes.

It is further recommended that this report, with appendices, be printed for planning purposes to guide public and private interests in studies for the protection and development of lands, waters, and other natural resources of the coastal areas.

E. J. RIBBS
Colonel, Corps of Engineers
Acting Division Engineer

APPENDICES

APPENDIX A - PRIOR STUDIES AND REPORTS

APPENDIX B - HISTORY OF HURRICANES AND OTHER STORM OCCURRENCES

APPENDIX C - DESIGN STUDIES AND HYDRAULICS

APPENDIX D - CONSIDERED PROTECTION PLANS

APPENDIX A

PRIOR STUDIES AND REPORTS

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APPENDIX A

PRIOR STUDIES AND REPORTS

A-1. HURRICANE

Detailed investigations have been made of the areas along the Massachusetts coast where heavy concentrations of tidal-flood damages have been experienced. These studies have resulted in the authorization of two hurricane tidal flood protection projects, one for the New Bedford-Fairhaven area, which is presently under construction, and another for the Wareham-Marion area. Details of the authorized projects listed in Table A-1 are available in the individual survey reports.

A-2. NAVIGATION

The coastline of Massachusetts has been the subject of numerous studies and reports which have resulted in the authorization of some 50 navigation projects. The authorized projects have been either completed or are now under construction. For details of the projects listed in Table A-1, see individual reports.

A-3. SHORE PROTECTION

The coastline of Massachusetts has been the subject of sixteen cooperative beach erosion control studies. The studies include Salisbury Beach and Plum Island along the north shore, Long Beach on Cape Ann, Lynn, Nahant, Revere, Winthrop, Quincy Shore, Wessagussett and Nantasket Beaches in the Metropolitan Boston area, the entire shore of Cape Cod Bay from Pemberton Point in Hull to Provincetown, the shore at Chatham and from Chatham to Point Gammon, the south shore of Falmouth and the city beaches at New Bedford.

Construction has been started or completed on 5 of the 12 projects authorized by these studies. Several additional projects developed by cooperative studies but not eligible for Federal aid have been built by the State entirely at its own expense.

Details of the authorized projects listed in Table A-1 are available in the individual reports.

TABLE A-1

PRIOR REPORTS - MASSACHUSETTS COASTAL AREA

Town	Project	Docu
Westport	Westport River	75th Cong. 3rd
New Bedford	New Bedford & Fairhaven Harbor	75th Cong.1st
	Clark Point*	87th Cong.2nd
Mattapoisett	Mattapoisett Harbor	80th Cong.2nd
Wareham	Wareham Harbor	54th Cong. 1st
Bourne	Channel from Buzzards Bay to Buttermilk Bay	80th Cong. 2nd
Gosnold (Cuttyhunk Is)	Canapitsit Channel	52nd Cong.1st
	Cutty Hunk Harbor	75th Cong.1st
Chilmark (Martha's Vineyard)	Menemsha Creek	76th Cong. 1st
Edgartown (Martha's Vineyard	Edgartown Harbor	74th Cong. 2nd on Comme
Tisbury (Martha's Vineyard)	Vineyard Haven Harbor	74th Cong. 1st
Nantucket	Nantucket Harbor	77th Con. 1st
Falmouth	Woods Hole Channel	43rd Cong. 1st
	Little Harbor	61st Cong. 2nd
	Falmouth Harbor	80th Cong. 2nd
Barnstable	Cotuit Harbor	86th Cong. 1st
	Hyannis Harbor	77th Cong. 1st
Nantucket Sound	Cross Rip Shoals	70th Cong. 1st
	Pollock Rip Shoals	62nd Cong. 2nd
Chatham	Chatham (Stage) Harbor	77th Cong. 1st
Provincetown	Provincetown Beach*	86th Cong. 2nd
	Provincetown Harbor	80th Cong. 2nd
Wellfleet	Wellfleet Harbor	76th Cong. 3rd
Eastham	Thumpertown Beach*	86th Cong. 2nd
Sandwich	Town Neck Beach*	86th Cong. 2nd
Sandwich & Bourne	Cape Cod Canal	67th Cong., 2nd
Sandwich	East Boat Basin	85th Cong. 1st
Plymouth	Plymouth Town Beach	86th Cong. 2nd
	Plymouth Harbor	87th Cong. 2nd
Kingston	Kingston Harbor	59th Cong. 1st
Duxbury	Duxbury Harbor	77th Congress

TABLE A-1 (cont)

PRIOR REPORTS- MASSACHUSETTS COASTAL AREA

Town	Project	Documen
Marshfield	Brant Rock Beach*	86th Cong. 2nd S
Scituate	North Scituate Beach	86th Cong. 2nd S
	Scituate Harbor	83rd Cong. 2nd S
Cohasset	Cohasset Harbor	76th Cong. 1st S
Hingham	Hingham Harbor	61st Cong. 2nd S
Weymouth	Weesagussett Beach*	86th Cong. 2nd S
	Weymouth Back River	72nd Cong. 1st S
	Town River	83rd Cong. 1st S
	Weymouth Fore River	82nd Cong. 2nd S
Quincy	Quincy Shore Beach*	82nd Cong. 1st S
Boston	Dorchester Bay and Neponset River	87th Cong. 2nd S
	Boston Harbor	84th Cong. 2nd S
	Mystic River	80th Cong. 2nd S
	Malden River	63rd Cong. 2nd S
Winthrop	Winthrop Harbor	57th Cong. 1st S
	Winthrop Beach*	80th Cong. 2nd S
Revere	Revere Beach*	82nd Cong. 1st S
Lynn-Nahant	Lynn-Nahant Beach*	82nd Cong. 1st S
	Lynn Harbor	81st Cong. 2nd S
Marblehead	Marblehead Harbor	87th Cong. 2nd S
Salem	Salem Harbor	85th Cong. 1st S
Beverly	Beverly Harbor	63rd Cong. 1st S
Manchester	Manchester Harbor	77th Cong. 1st S
Gloucester	Gloucester Harbor and Annisquam R.	87th Cong. 2nd S
Rockport	Rockport Harbor	56th Cong. 1st S
	Harbor of Refuge at Sandy Bay	64 Cong. 1st Ses
Essex	Essex River	44th Cong. 1st S
Ipswich	Ipswich River	Annual Report Ch
Newburyport	Newburyport Harbor	76th Cong. 3rd S
	Merrimack River	59th Cong. 2nd S
New Bedford-Fairhaven	New Bedford H	85th Congress 1s
Wareham-Marion	Wareham H	87th Cong. 2nd S

* Shore Protection Projects

H - Hurricane Protection Projects

APPENDIX B

HISTORY OF HURRICANES AND OTHER STORMS

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APPENDIX B

HISTORY OF HURRICANES AND OTHER STORMS

B-1. GENERAL

A review, to determine the future possibility of major storm occurrence, has been made of historical data on hurricanes and northeast storms that have affected the Massachusetts coastline. The southern coastline, including Buzzards Bay, the outer Islands, and the south shore of Cape Cod, has experienced or has been threatened by hurricane tidal flooding upon 71 occasions during the period from 1635 to date. (1965) The Massachusetts coastline from Provincetown to the New Hampshire line has been affected more severely and far more often by northeast storms than by hurricanes. The northeast storms that are responsible for most of the damage sustained along this reach occur during late fall, winter, and early spring.

B-2. SUMMARY OF HURRICANES AND OTHER STORMS

Of the 71 hurricanes of record that hit or narrowly missed the south shore of Massachusetts, 13 caused severe tidal flooding, 25 caused damage from wind and rain and were usually accompanied by high seas and moderate tidal flooding, and 33 threatened the area. The seven hurricanes which have created the greatest tidal flooding along the south coast listed in order of magnitude are as follows: August 3, 1638; August 15, 1635; September 21, 1938; August 31, 1954; September 23, 1815; September 14, 1944; September 12, 1960.

A summary of gales occurring at Boston during the 75 year period from 1870 to 1945 shows that of 160 storms with continuous winds over 32 miles per hour, 80 of them came from the northeast quadrant. The northeast storms in the past have caused exceptionally high tides along the coast. A storm on February 24, 1723 is reported to have caused a tide height at Boston of about 15.4 above mean low water (10.5 above mean sea level). Storms with the maximum tide heights in feet above mean sea level at Boston are given in Table B-1.

During the April 22, 1940 storm, heavy surf pounded the coast and spray was reported to have dashed over the 110-foot tower at Minot's Light off Scituate and to have carried 25 feet above the 105-foot cliff on Deer Island in Boston Harbor. Many northeast storms, which occurred at times of lower tidal elevation, have caused extensive damage to shore structures due to violent wave action, such as occurred in January 1961.

B-3. HURRICANE TRACKS

The tracks of three notable hurricanes causing tidal flooding and serious damages along the Massachusetts coast, namely, those of September 1938, September 1944, and August 1954, and Hurricane Diane, August 1955, which brought record rainfall to many areas in southern New England, are illustrated on the following plate, "Tracks of Selected Hurricanes."

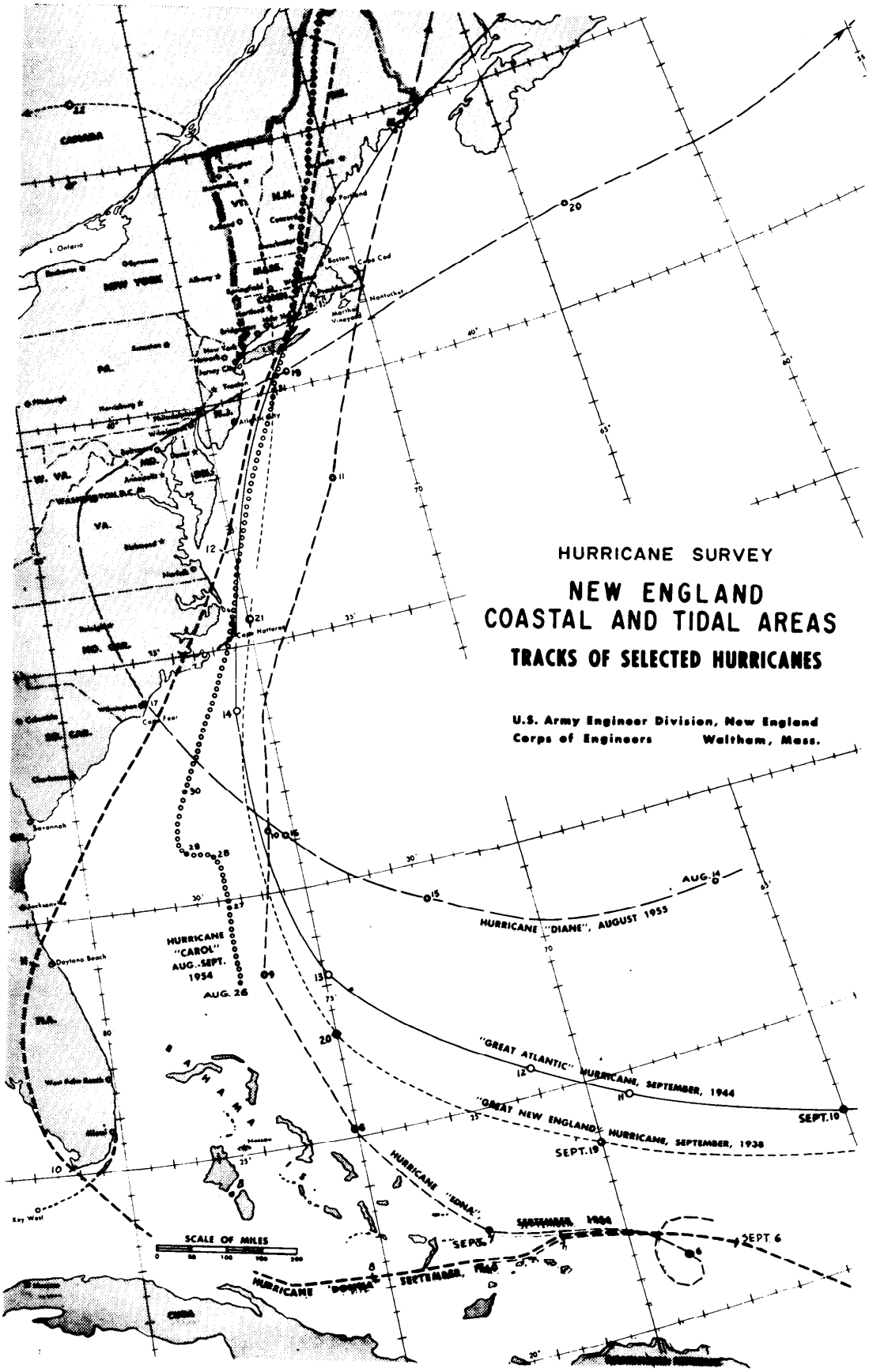
TABLE B-1

MAXIMUM STORM TIDE HEIGHTS
BOSTON, MASSACHUSETTS

Date	Elevation (ft. above msl)
24 February 1723	10.5
16 April 1851	10.0
26 December 1909	10.0
27 November 1898	9.5
29 December 1959	9.4
21 April 1940	9.0
4 March 1931	8.8
30 November 1944	8.8
20 January 1961	8.8
7 March 1956	8.6
7 April 1958	8.5
28 January 1933	8.3
2 April 1958	8.3
10 November 1947	8.2
28 February1958	8.2
7 March 1962	8.2
27 January 1933	8.1
13 April 1953	8.1
25 October 1953	8.1
1 April 1958	8.1
28 March 1959	8.1
30 December 1959	8.1
4 March 1960	8.1
21 December 1960	8.1
23 October 1961	8.1

Note: Conversion from M.S.L. to M.H.W. -4.6 (Boston Naval Shipyard,Charlestown)

Conversion from M.S.L. to M.L.W. +4.9 (Boston Naval Shipyard,Charlestown)


HURRICANE SURVEY
NEW ENGLAND
COASTAL AND TIDAL AREAS
TRACKS OF SELECTED HURRICANES
U.S. Army Engineer Division, New England
Corps of Engineers Waltham, Mass.
HURRICANE "DIANE", AUGUST 1955
AUG. 14
AUG. 15
HURRICANE "CAROL" AUG.-SEPT. 1954
AUG. 26
"GREAT ATLANTIC" HURRICANE, SEPTEMBER, 1944
SEPT. 10
"GREAT NEW ENGLAND" HURRICANE, SEPTEMBER, 1938
SEPT. 19
HURRICANE "EDNA", SEPTEMBER, 1954
SEPT. 6
HURRICANE "DONNA", SEPTEMBER, 1960
SCALE OF MILES
0 50 100 150 200
CANADA
CUBA
Boston
Cape Cod
Nantucket
Martha's Vineyard
Portland
Cape Hatteras
Cape Fear
Savannah
Daytona Beach
Key West
Nassau

APPENDIX C

DESIGN STUDIES AND HYDRAULICS

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APPENDIX C

DESIGN STUDIES AND HYDRAULICS

INTRODUCTION

C-1. INTRODUCTION

This appendix gives design features and hydraulic data to supplement the sections of the main report. This information is presented as a guide for the use of public and private agencies in developing protection against tidal flooding, wave forces or a combination thereof.

C-2. DESIGN CRITERIA

The structures would be designed for protection against a flood of record storm. They would either reinforce existing structures or be considered in problem areas where no protection exists.

The design of structures has followed published standards of the Chief of Engineers and Beach Erosion Board. The design of rock armor is based on general criteria developed by the Waterways Experiment Station, Vicksburg, Mississippi, and berm widths and beach slopes for beach raising and widening was established by the method outlined in a paper titled "Wave Run-up on Composite Slopes" by Thorndike Saville, Jr., Beach Erosion Board,Washington,D.C.

C-3. DESCRIPTION OF PLANS

Plans of protection were considered based on the type of problem that exists. For the Boston area from Hull to Manchester the problems are complex and would require a major study beyond the scope of this report to develop necessary construction incorporated with long range redevelopment plans. These plans, which would consider tidal flooding

and wave protection and incorporate related resource development would be of considerable magnitude ranging from off shore barrier or breakwater studies in harbor areas to river closures which might incorporate navigation locks such as presently under design by the Commonwealth of Massachusetts for the Mystic River or even in some cases shorefront dikes and appurtenant structures. The following types of protection considered for locations outside of the Boston complex are as follows:

a. Rock Revetment. This type of construction is suitable for reinforcing headlands or cliffs exposed to continuous erosion during hurricanes, or serious storms. Revetment in front of existing concrete walls would be considered as a means of erosion control to minimize undermining of walls, or to reduce overtopping and destruction of walls by absorption of the energy of waves breaking on the rock face. The heavier revetment would be placed on filter stone on a gravel base. See Appendix D, plate D-1 for details.

b. Beach Raising and Widening. In some locations where the sand fill forms a natural beach wave overtopping would occur during serious storms. In general, remedial measures would provide a sand fill berm backing up a flat beach slope. A backstop would consist of an earth fill, rock faced dike, or a precast concrete wall, or natural sand dunes. In some locations where concrete walls exist that are subject to wave damage and overtopping, beach raising and widening would dissipate wave energy in front of the wall and reduce erosion. See Appendix D, Plate D-3 for details.

c. Dikes. (Earthfill rock faced or rock fill). Dike protection is suitable for certain locations. The earthfill rock faced dikes fronting shorefront developments may offer both tidal flood and wave protection. Rock dikes along sandfill spits or bars offer breakwater protection to harbors and shorefront properties formed by these offshore beaches as well as reinforcing the beaches against a breakthrough. Earthfill dikes faced with rock riprap would be considered along some tidal inlets to prevent tidal flooding of shorefront properties. These dikes would have lighter armor and lower top grade elevations than those exposed to the full force of ocean waves. See Appendix D - Plate D-3 for details.

d. Dune Reinforcement. Dune reinforcement in general would be accomplished by rock revetment especially in places where the dunes are high and tend to be undercut at the base. In some areas where the dunes are low with intermediate breakthroughs, often man made, building up the dunes by replenishment of sand could be accomplished or the dunes stabilized by planting beach grass. The dunes may be utilized as a backstop for the improved beach. See Appendix D-Plate D-3 for details.

C-4. HYDRAULICS

In general the coastal reach north of Cape Cod has not been subjected to serious flooding or wave forces from hurricanes. The paths of hurricanes as shown in Appendix B either veer off the coast of Cape Cod or travel inland minimizing coastal effects. For northern New England, paths producing the strongest onshore winds would be from a south through east direction. However, since 1887, only two weak tropical storms

moved into northern New England from a direction east of south. The Buzzards Bay area and the southern shore of Cape Cod, however, have been subjected to serious wave attack and tidal flooding from hurricanes.

Over the years the entire coast has been subject to serious tidal flooding and wave forces from frequent coastal storms. Some general information on hydraulic features are described as follows:

a. Comparison of Hurricanes and Northeasters in Northern New England. From a comparison of disastrous hurricanes and damaging northeasters in northern New England one can conclude that although hurricanes have higher wind speeds, they normally move with a faster forward speed, have a smaller area of strong winds, and shorter fetch lengths than northeasters. The surge-producing effects of hurricanes lasts for a shorter length of time. Northeasters usually have a longer duration and have produced higher surges north of Cape Cod; this may, however, be due to the relatively short period of record.(1)

b. Winds. The most reliable data on experienced hurricane wind velocities in New England begin with the September 1938 hurricane. The maximum velocity recorded in New England was a gust of 186 miles per hour from the south at the Blue Hill Observatory in Milton, Mass. where a sustained 5 minute wind of 121 miles per hour was also recorded. The 1944 hurricane had recorded 5 minute velocities ranging from 33 miles per hour to 85 miles per hour at a number of locations along the Massachusetts Coast. Hurricane Carol (31 August 1954) had gusts of 125-135 miles per hour experienced at Blue Hill Observatory. Sustained

(1) Report No. 68, National Hurricane Research Project, USWB, March 1964

velocities from 38 to 98 miles per hour were registered. In all cases the direction of winds had a southerly approach.

Wind velocities from frequent winter storms with wind velocities varying from 35 to 70 miles per hour (gusting to 90 m.p.h.) have been reported. In the period from December 1957 to April 1958, 18 winter storms occurred with wind velocities varying from 35 m.p.h. to 60 m.p.h. More recently in November 1963, a fast moving storm coupled with high spring tides and heavy wave action had southwest winds gusting to 90 m.p.h.

c. Tidal Flooding. The stillwater level for design of structures is normally based on the largest flood expected to occur, based on records of past hurricanes and storms. The hurricane levels have been recorded above 14 feet m.s.l. in the Buzzards Bay area and above 10 feet for the south shore of Cape Cod. A winter storm in December 1959 had flooding about 10 feet above mean sea level along the shorefront north of Cape Cod. Many storms have had flood levels 4 to 5 feet above mean high water at various locations along the coast. See Table B-1, Maximum Storm Tide Heights, Boston, Massachusetts .

d. Waves. The design wave height at the toe of shore protection are calculated on the premise that the maximum wave height is limited to 0.78 times the water depth at the toe of the structure.

APPENDIX D

CONSIDERED PROTECTION PLANS

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CONSIDERED PROTECTION PLANS

D-1. GENERAL

The tidal flood problem on the Massachusetts Coastal area may be separated into three segments, as follows: (a) the area east of the Rhode Island-Massachusetts State line to and including Buzzards Bay, (b) the south shore of Cape Cod, including offshore islands, and (c) the north shore of Cape Cod and the Massachusetts Bay area extending from Sagamore to the Massachusetts-New Hampshire State line. The coastal areas are shown on 6 Plates, D-1 through D-6.

D-2. BUZZARDS BAY AREA EAST OF RHODE ISLAND LINE

This is the area that has suffered the greatest monetary losses in past hurricane tidal floods. The area includes the manufacturing center of the area at New Bedford and popular recreation areas on Buzzards Bay. The area extends from the Rhode Island-Massachusetts line to Woods Hole in Falmouth on the western end of Cape Cod and includes six towns and the city of New Bedford. The total population in 1960 was about 153,000 of which 70 percent is concentrated in New Bedford.

The record hurricane tidal flood occurred in 1938. Flood losses (levels) at that time varied from 12.2 feet above m.s.l. in the western end of the area to 14.2 feet, m.s.l. at Bourne, the Buzzards Bay end of the Cape Cod Canal. This compares with a normal mean high water level of 1.4 feet, msl, at the western end of the area, and 2.4 feet, msl, at Bourne. Recurrence of the record levels under present

day conditions would cause tidal flood losses estimated at $57,500,000. The principal damage centers at New Bedford and Wareham would account for over $52,000,000 of the loss. About $50,000,000 of the losses would be prevented upon completion of hurricane barrier projects authorized by the Congress for these communities.

Except for a concentrated damage area in Dartmouth, the remainder of the reach suffers damage principally through erosion of beaches and flooding of seasonal dwellings. At Dartmouth, the Apponagansett Bay area could receive a high degree of protection from the construction of a barrier structure with partially gated navigation opening. No project is recommended at this time as there is no indication that the community desires or is willing to participate in the cost of the structure.

Future tidal flood damages in the area may be lessened through local planning to control future construction in vulnerable areas, to require flood-proofing measures of elevating dwellings now situated in flood-prone areas, to establish evacuation plans for future hurricane events and through the establishment of evacuation routes constructed at a level above the expected flood height.

The beaches may be protected and maintained through widening and raising with sand fill and the construction of groins. Where damage occurs shoreward of the beach, dikes or revetment could be erected. The areas subject to flooding and typical plans for protection are shown on Plates D-1 and D-2.

D-3. SOUTH SHORE OF CAPE COD

This area extends from Woods Hole in Falmouth to Chatham and excludes the Cape Cod National Seashore area.

The area includes the warm water bathing beaches fronting Nantucket Sound, and many tidal coves and inlets extensively used for recreational boating. The entire area has had a high rate of growth since 1950 and demands for shore frontage threaten to create development over the entire area except for stretches which have been reserved for public use.

The record hurricane tidal flood occurred in 1944. Flood levels at that time varied from 11.0 feet above msl at Woods Hole to 9.3 feet above msl at Chatham. The entire stretch from Bass River, Yarmouth east to Chatham experienced a level of 9.3 feet above msl. West of Bass River entrance the tide level gradually increased. Normal high water levels vary from about 0.5 feet msl at Woods Hole to 1.9 feet msl at Chatham. Recurrence of the record flood levels under present conditions would cause tidal flood losses estimated at $5,800,000. This does not include storm damage to beaches and shore structures.

The tidal flood damage is distributed over the entire shoreline with few areas of concentrated damage. Studies of protective possibilities through structural measures indicate that tidal flood damage prevention measures are not warranted at this time. Since long stretches of shoreline remain in private ownership Federal participation on beach protection would not be justified. Local governing bodies have a wide choice

of preventative measures to decrease future tidal flood losses. These include ordinances to control future construction, the formulation of plans for the evacuation of flood-prone areas, and the construction of escape roads from such areas. Beach protection measures may be accomplished through widening and raising with sand fill retained by groins, or the beaches supplied from strategically located stockpiles. Where damage occurs shoreward of the beach, the natural dunes may be restored and protected. Dikes and revetment would be effective in some locations. The areas subject to flooding and typical plans of protection are shown on Plates No. D-2 and D-6.

D-4. NORTH SHORE CAPE COD AND COAST FROM SAGAMORE TO NEW HAMPSHIRE STATE LINE

This area, including the north shore of Cape Cod extends from Sagamore at the eastern entrance of Cape Cod Canal to the New Hampshire State line and includes 14 cities and 23 towns. The population, 1960 census, was about 1,600,000 of which about 70 percent is in Boston and adjacent cities.

The topographical features vary from offshore barrier beaches fronting harbors such as at Plymouth and adjacent areas south of Boston to rocky headlands flanking pocket beaches, tidal marsh areas and inlets in the area north of Boston. Many fine beaches attract visitors, especially those located near densely populated areas, such as Metropolitan Boston.

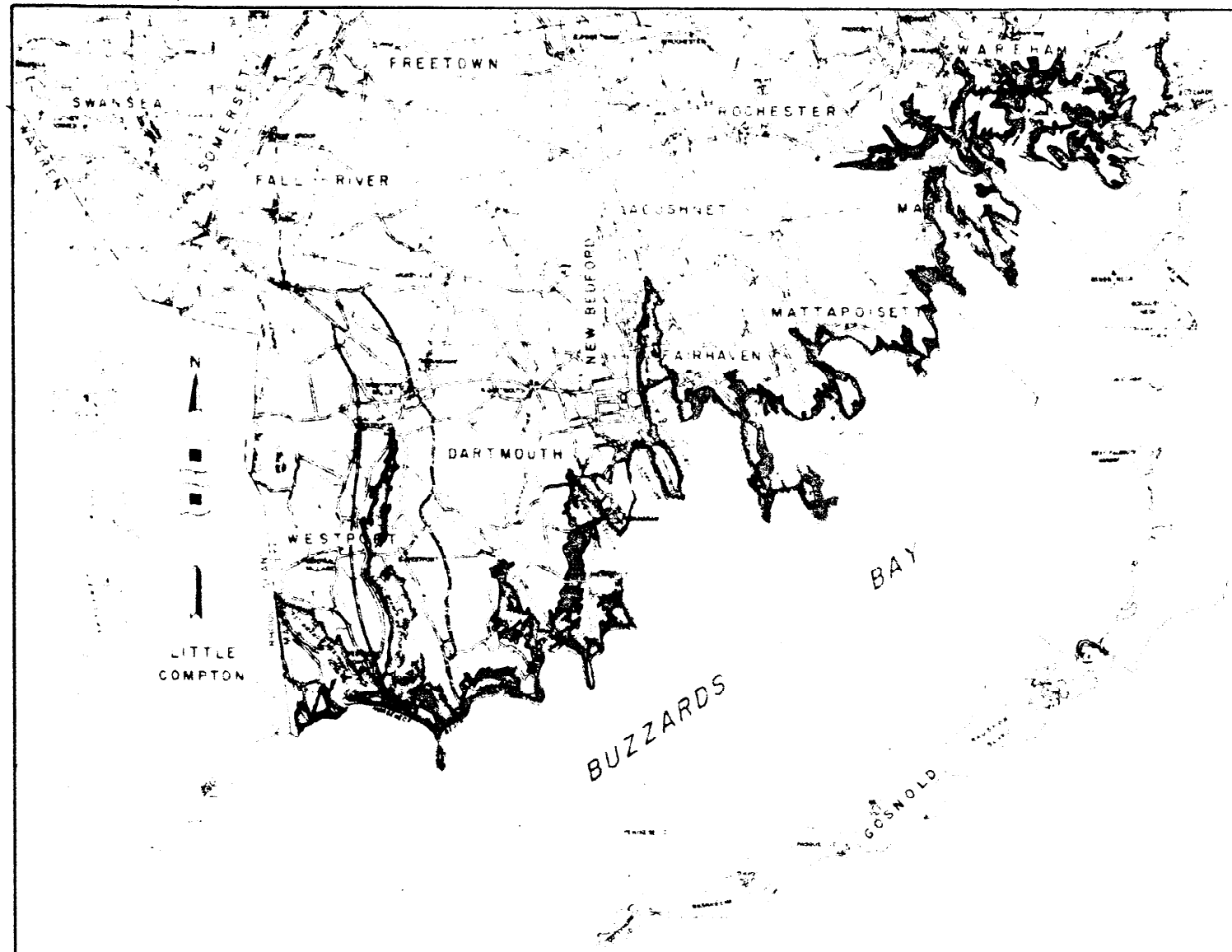
The north side of Cape Cod and shorefront areas northward have not experienced serious hurricane damages in the past; it is, instead, more vulnerable to northeast storms. These storms, occurring more

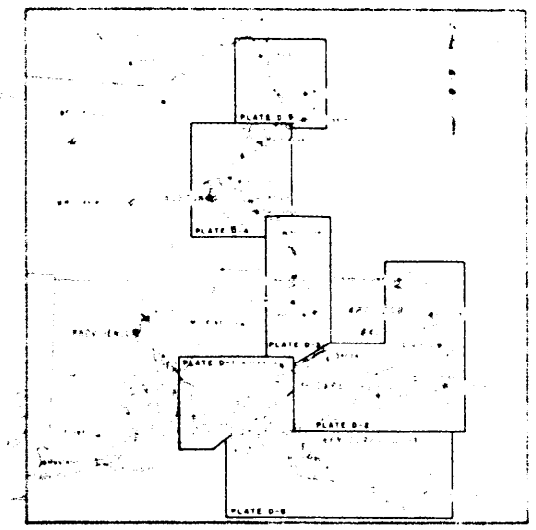
frequently than hurricanes, have caused serious tidal flooding and erosion problems. Tide heights ranging as high as 10.5 feet above mean sea level have occurred at Boston as compared to a normal high water level of 4.6 feet above mean sea level. For information on flood levels of some of the major northeast storms, see Appendix B, Table B-1. Due to the complex nature of the topography damages are sporadic. It is estimated that storms of the magnitude of the January 1961 storm with a flood level of 8.8 feet above mean sea level could cause damages of about $10,000,000.

Protection does not appear feasible at this time except that it is recommended that studies of tidal flood protection be made for the Saugus-Pines Rivers area. Plates D-2 through D-5 show flood-prone areas and typical methods of protection. Tidal flooding and erosion could be decreased by such methods as raising and widening beaches to controlling inland flooding and erosion of other shorefront areas by construction of dikes or revetment. Low dikes, flood walls and artificial dunes may be utilized to prevent overtopping of the beaches.

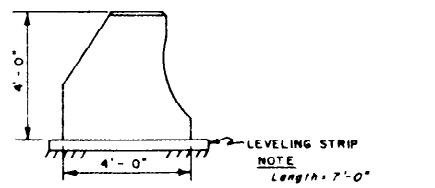
CORPS OF ENGINEERS

U. S. ARMY



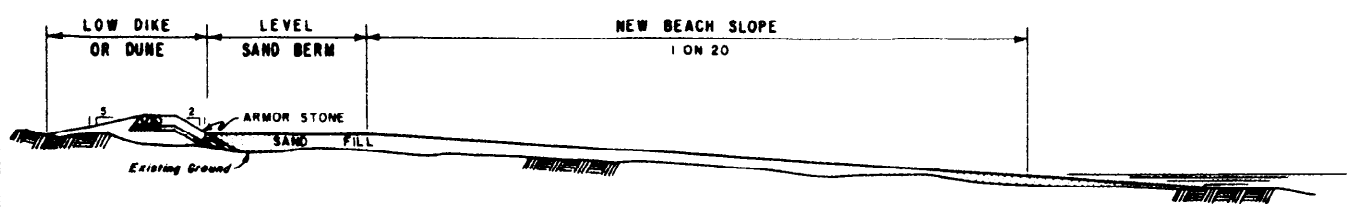


SCALE IN FEET
8000 0 8000 16,000



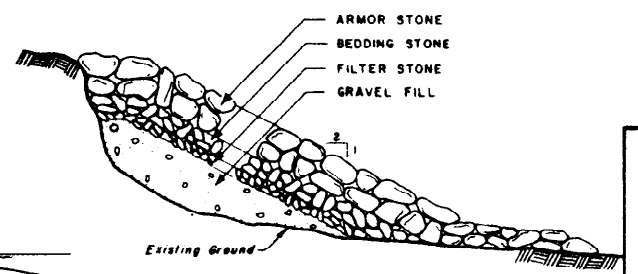
TYPICAL PRECAST CONCRETE FLOOD WALL

NOT TO SCALE



TYPICAL BEACH RAISING AND WIDENING WITH BACKSTOP

SCALE IN FEET
20' 0 20' 40'



TYPICAL REVETMENT

SCALE IN FEET
10' 0 10' 20'

LEGEND:

AREAS SUBJECT TO TIDAL FLOODING.

HURRICANE SURVEY

MASSACHUSETTS COASTAL AND TIDAL AREAS

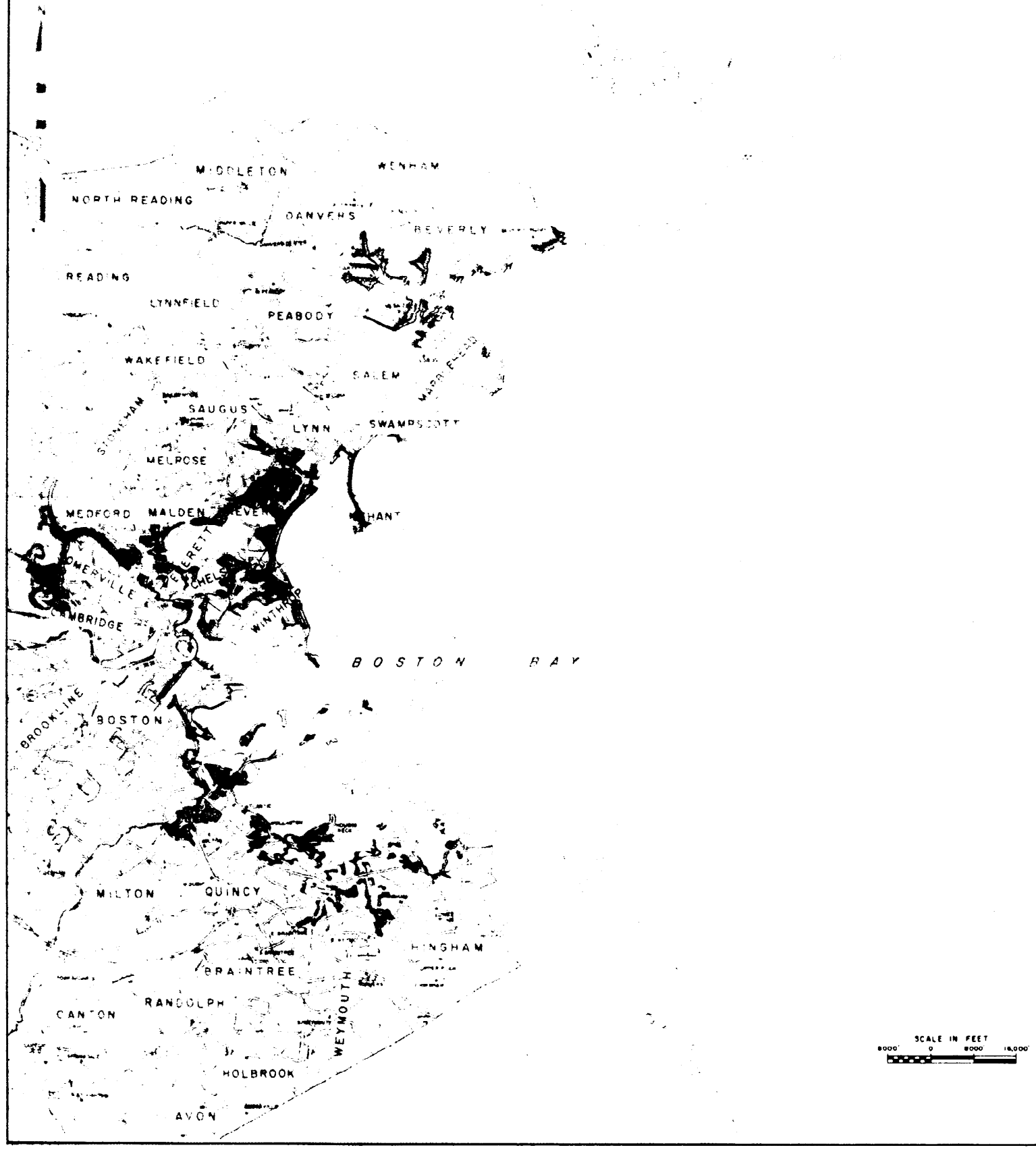
BUZZARDS BAY

U.S. ARMY ENGINEER DIVISION, NEW ENGLAND
CORPS OF ENGINEERS
WALTHAM, MASS. JUNE 1964
SCALE AS SHOWN

PLATE D-1

CORPS OF ENGINEERS

U. S. ARMY



LEGEND:

AREAS SUBJECT TO TIDAL FLOODING.

HURRICANE SURVEY

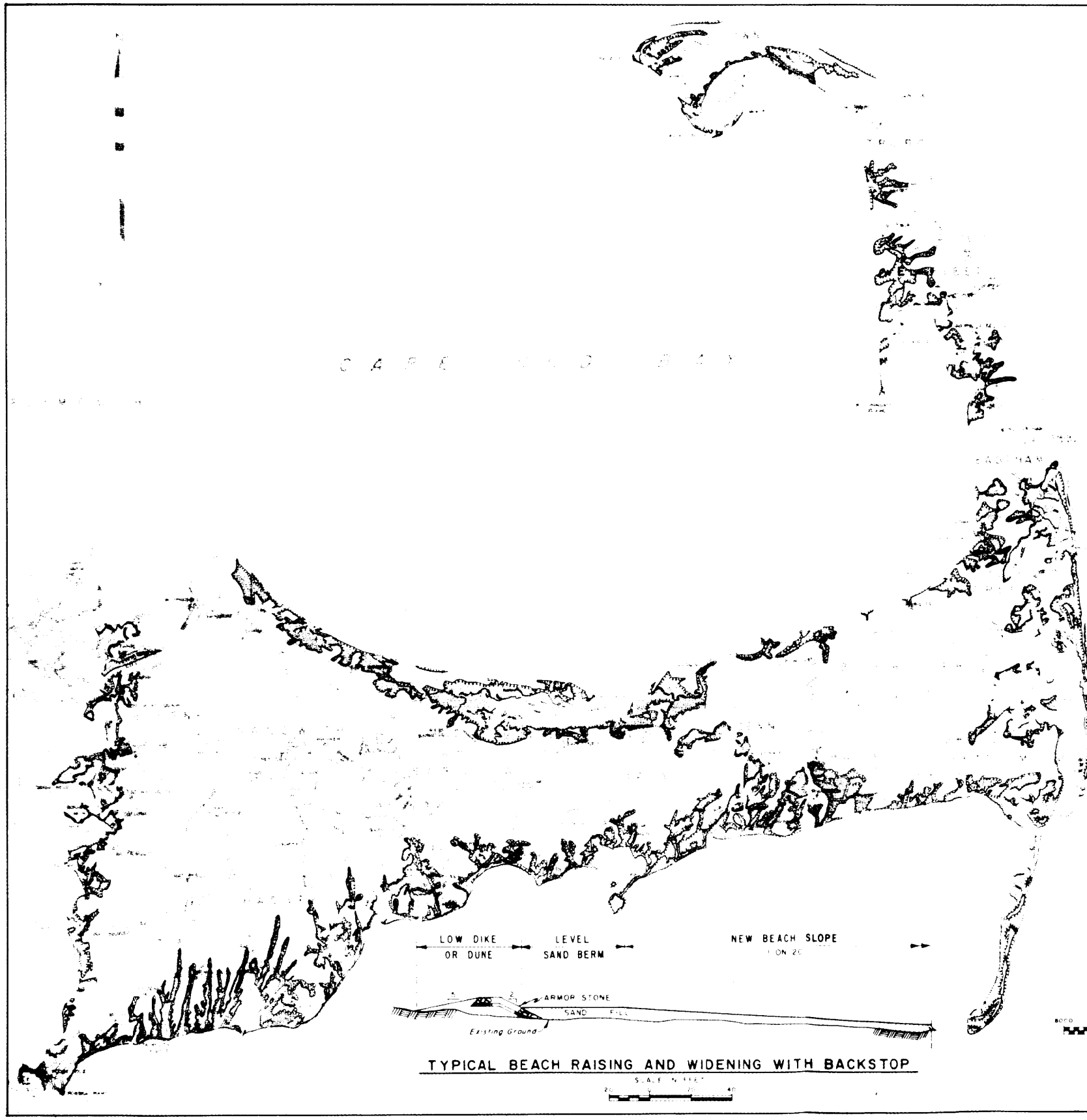
MASSACHUSETTS COASTAL AND TIDAL AREAS

BOSTON

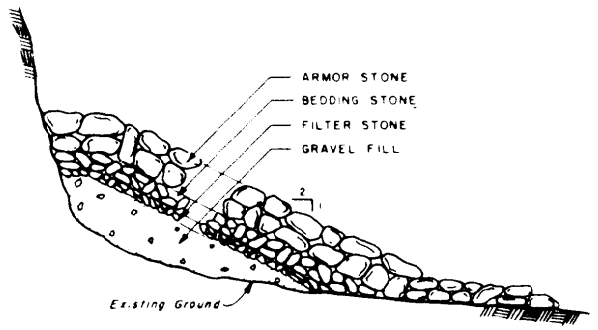
U.S. ARMY ENGINEER DIVISION, NEW ENGLAND
CORPS OF ENGINEERS
WALTHAM, MASS. JUNE 1964
SCALE AS SHOWN

PLATE D-4

53-944 O-65 (Face p. 46) No. 4

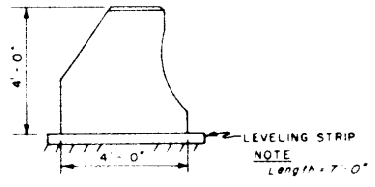


TYPICAL BEACH RAISING AND WIDENING WITH BACKSTOP



TYPICAL REVETMENT OF SAND CLIFFS

SCALE IN FEET
0 10 20



NOTE
Length 7'-0"

TYPICAL PRECAST CONCRETE FLOOD WALL
NOT TO SCALE

SCALE IN FEET
8000 0 8000 16,000

LEGEND:

AREAS SUBJECT TO TIDAL FLOODING

HURRICANE SURVEY

MASSACHUSETTS COASTAL AND TIDAL AREAS

CAPE COD

U.S. ARMY ENGINEER DIVISION, NEW ENGLAND
CORPS OF ENGINEERS
WALTHAM, MASS. JUNE 1964
SCALE AS SHOWN

PLATE D-2

53 944 O 65 (Face p. 46) No. 2

U S ARMY

CORPS OF ENGINEERS

HURRICANE SURVEY

MASSACHUSETTS
COASTAL AND TIDAL AREAS
SOUTH SHORE

LEGEND

AREAS SUBJECT TO TIDAL FLOODING

EARTH DIKE

TYPICAL BEACH RAISING AND WIDENING WITH BACKSTOP

LOW DIKE OR DUNE — LEVEL SAND BERM — NEW BEACH SLOPE

TYPICAL PRECAST CONCRETE FLOOD WALL

TYPICAL REVETMENT

TYPICAL ROCK DIKE

TYPICAL EARTH FILLED-ROCK FACED DIKE

TYPICAL PROTECTION FOR EXISTING WALLS

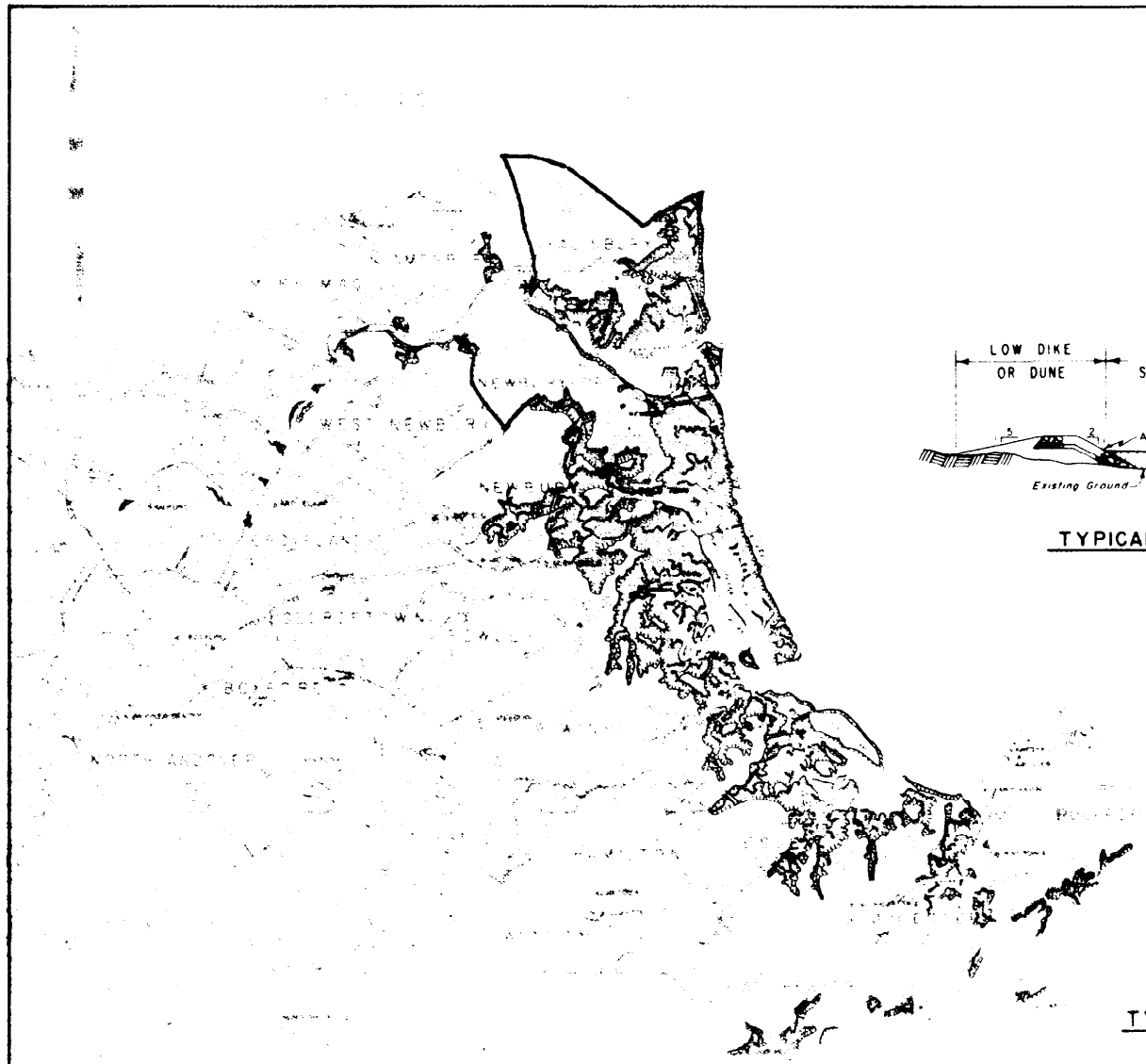
BUILT-UP BEACH METHOD

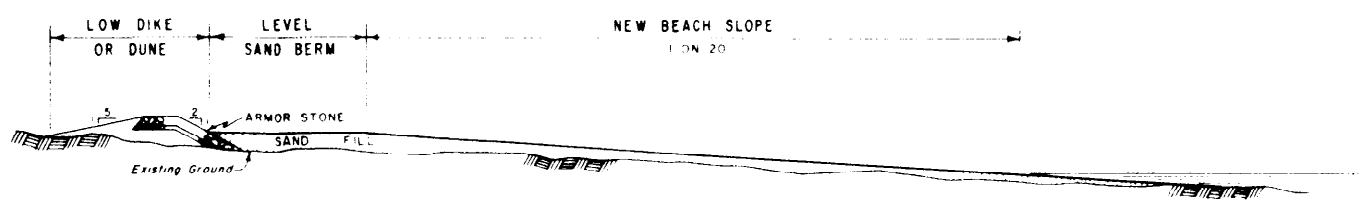
REVETMENT METHOD

53 OHIO 03 (Exc p 16) No. 3

CORPS OF ENGINEERS

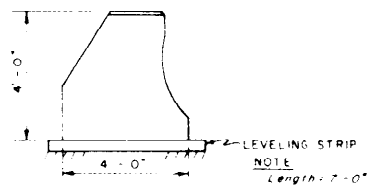
U. S. ARMY





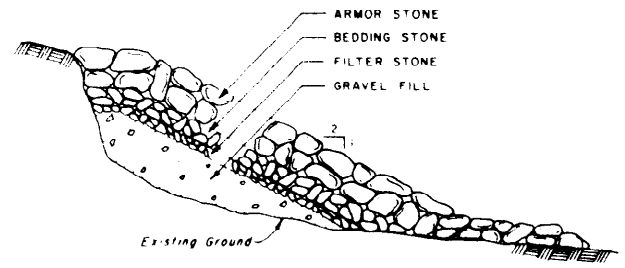
TYPICAL BEACH RAISING AND WIDENING WITH BACKSTOP

SCALE IN FEET



TYPICAL PRECAST CONCRETE FLOOD WALL

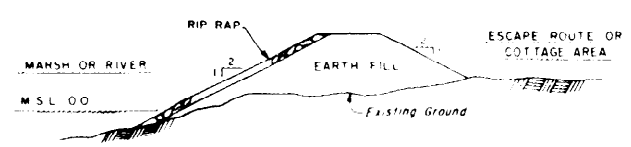
NOT TO SCALE



TYPICAL REVETMENT

SCALE IN FEET

0 10 20



EARTH DIKE

SCALE IN FEET

8000 0 8000 16,000

LEGEND:

AREAS SUBJECT TO TIDAL FLOODING

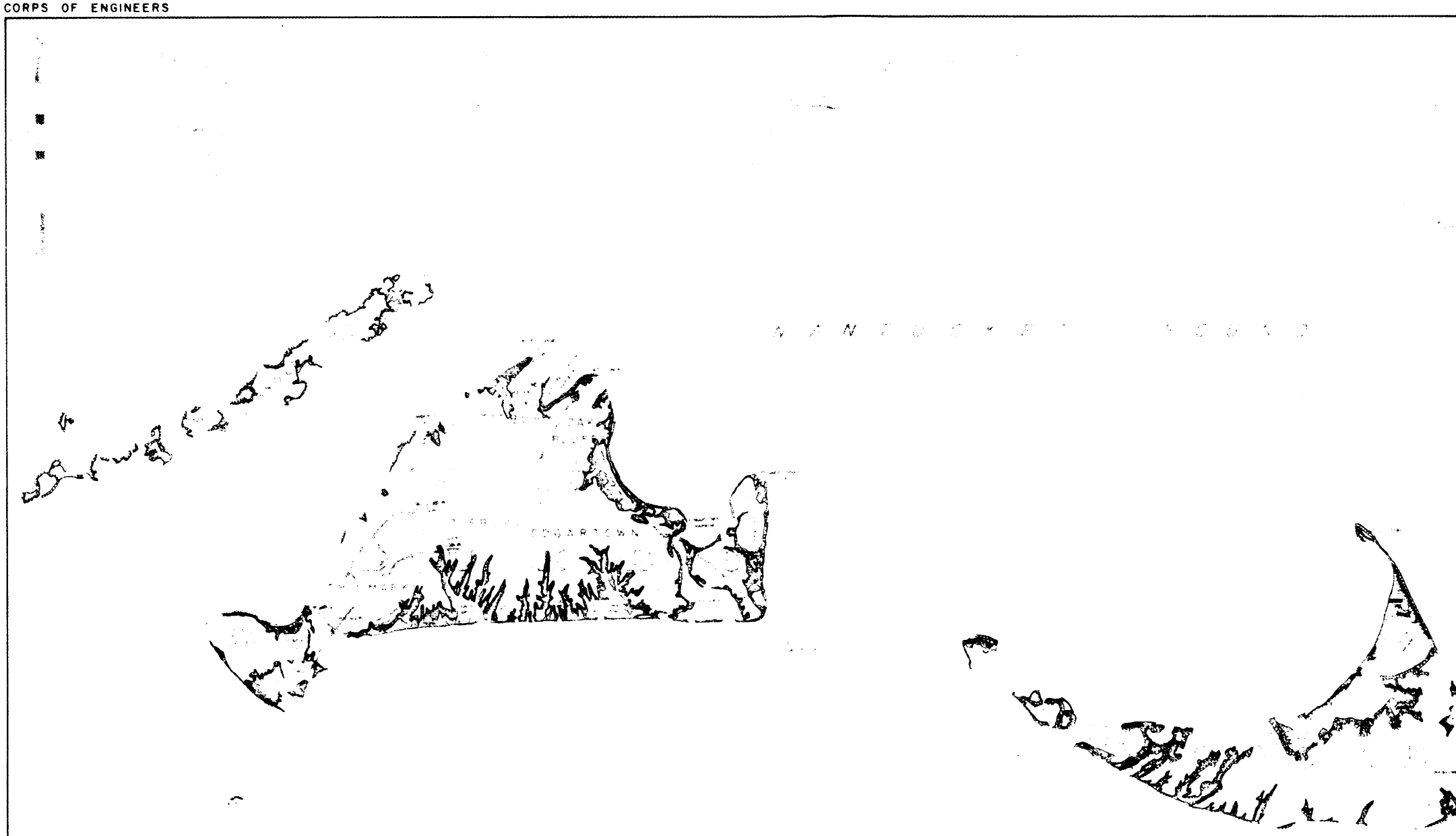
HURRICANE SURVEY

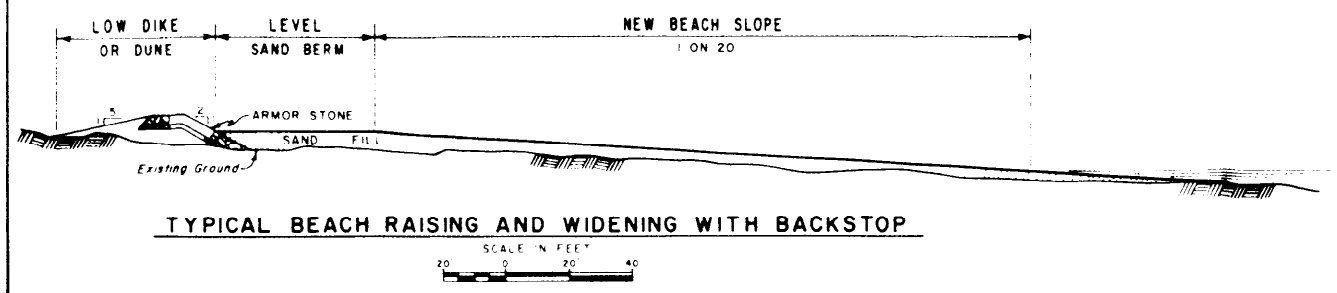
MASSACHUSETTS COASTAL AND TIDAL AREAS

NORTH SHORE

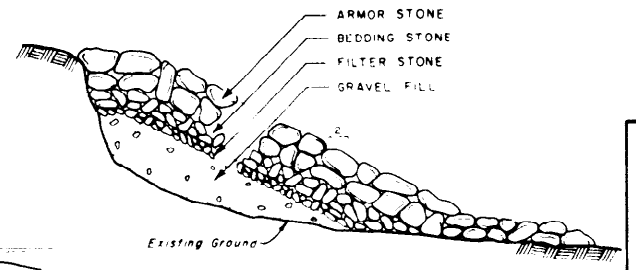
U.S. ARMY ENGINEER DIVISION, NEW ENGLAND
CORPS OF ENGINEERS
WALTHAM, MASS. JUNE 1964
SCALE AS SHOWN

PLATE D-5





TYPICAL BEACH RAISING AND WIDENING WITH BACKSTOP



TYPICAL REVETMENT

LEGEND:

AREAS SUBJECT TO TIDAL FLOODING.

HURRICANE SURVEY

MASSACHUSETTS COASTAL AND TIDAL AREAS

OUTER ISLANDS

U.S. ARMY ENGINEER DIVISION, NEW ENGLAND
CORPS OF ENGINEERS
WALTHAM, MASS. JUNE 1964
SCALE AS SHOWN

PLATE D-6